Optimization on CFRP manufacturing processes by using automated thermography

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DLR

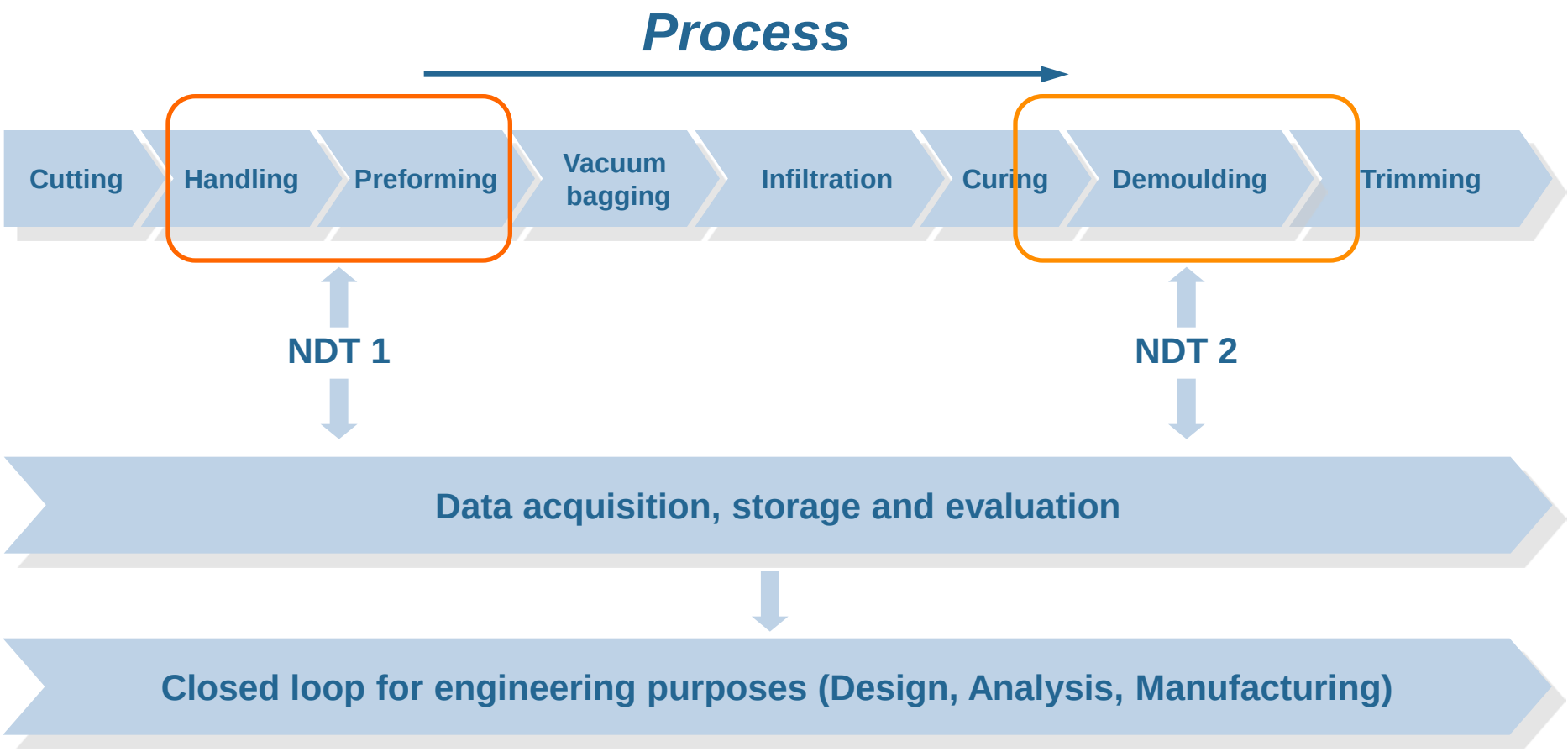
Outline

- Motivation and context
- Approach – production integrated, automated thermography
- Preparation
- Use case description
- Results
- Summary
- Outlook

Motivation and Context

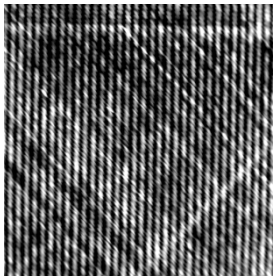
- High demand on CFRP production capacity, currently and still growing
- Trend towards larger but tailored parts with high level of structural integration
- Requirements
  - increase quality, throughput, layup rate, level of automation, health and safety conditions
  - Decrease production cost, rework, manual labor, processing time
- Choice of process chain towards dry textile layup with subsequent infiltration
  - Modern NCFs and other textile architectures have excellent mechanical properties
  - Modern resin systems are customized to fulfill aerospace requirements Reduced process cost
  - No cooling chain
  - Added value on the manufacturer side, but risk and responsibility as well
- **Eligibility of production integrated quality assurance**

Approach

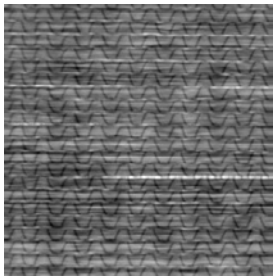

Process
Cutting
Handling
Preforming
Vacuum bagging
Infiltration
Curing
Demoulding
Trimming
NDT 1
NDT 2
Data acquisition, storage and evaluation
Closed loop for engineering purposes (Design, Analysis, Manufacturing)

Choice of method - optically excited lock-in thermography

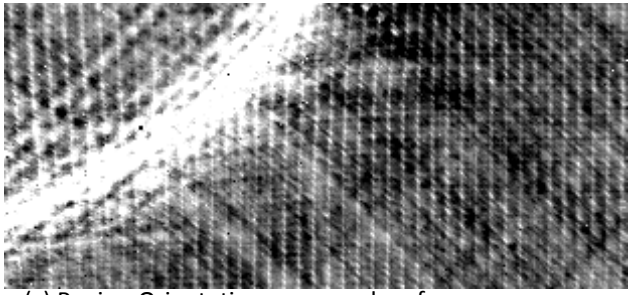
Dry textiles at preform stage



(a) Missing Roving



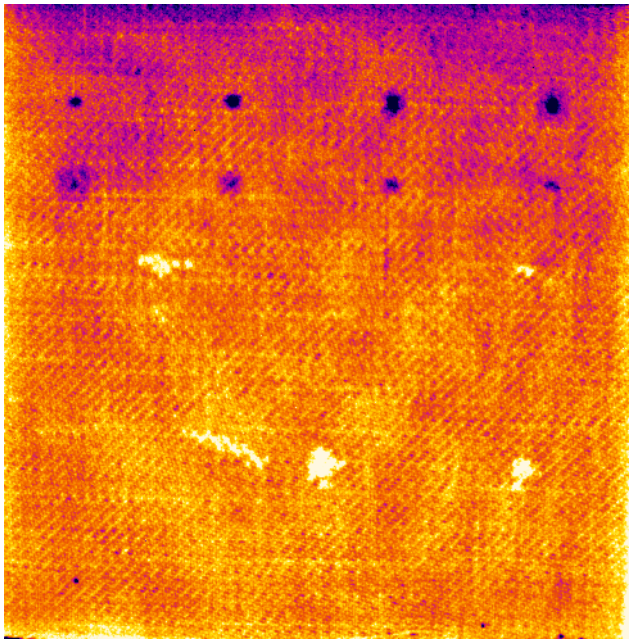
(b) Gaps



(c) Roving-Orientation on curved surface

Fiber orientation
Ply position

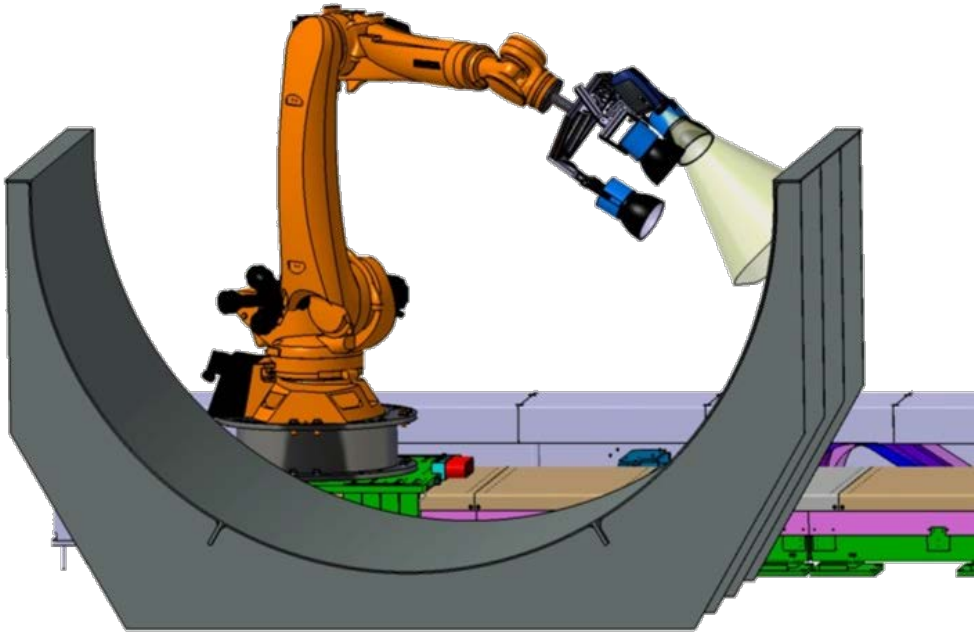
Cured part at final stage



2D- Defects (Delamination)
3D- Defects (Porosity, Dry spots)

Challenges

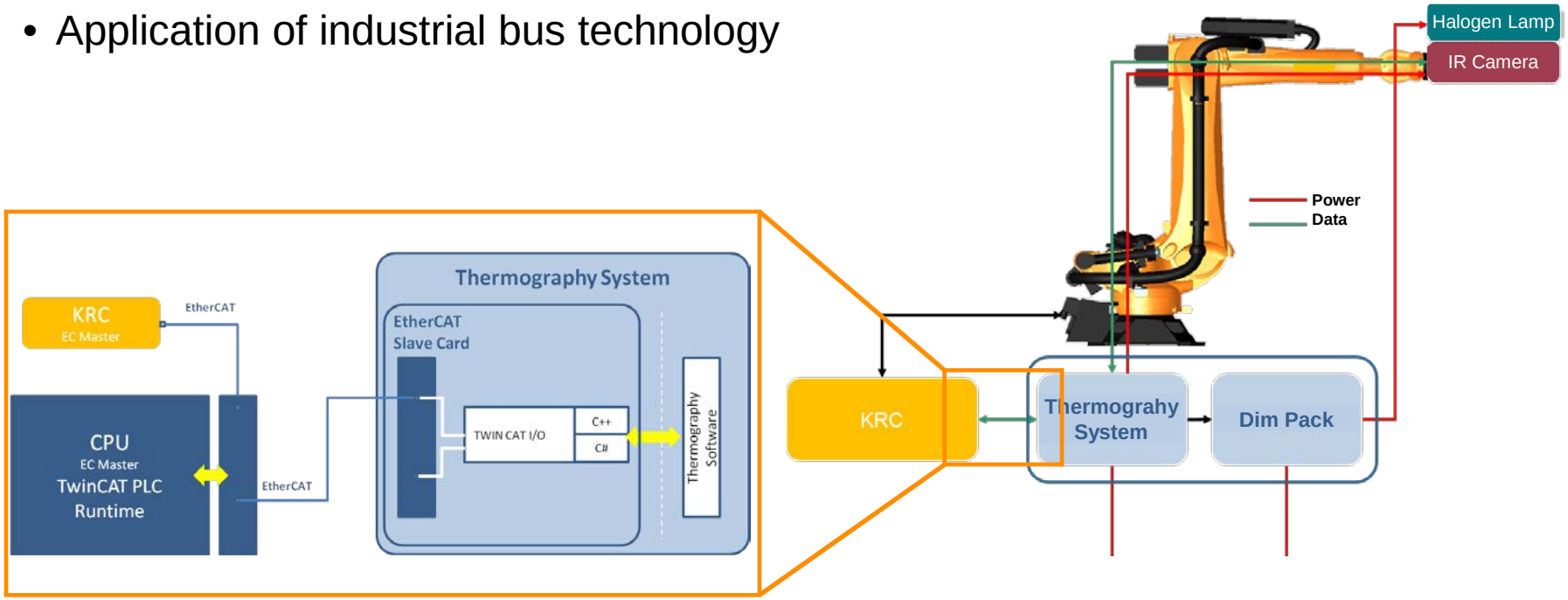
- Parts to be measured are larger than field of view
- Reduce manual effort
- Reduce cost
- Precise positioning



Need on automation to enable to measure larger part → tiling with a flexible manipulator including accurate positioning of camera during measurement to allow defect localization

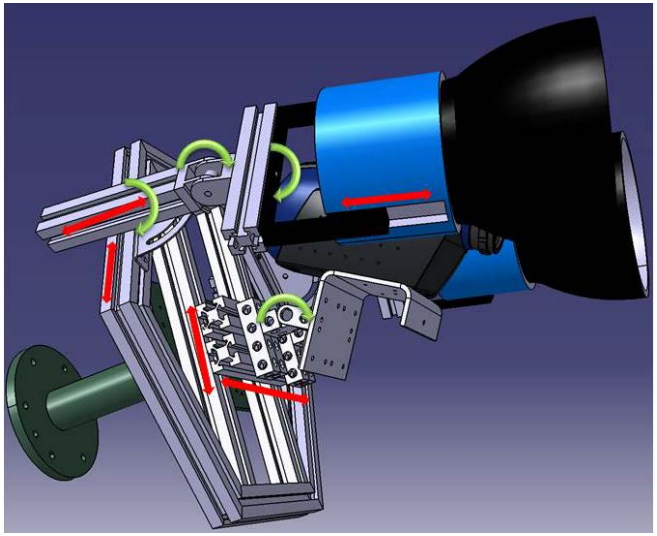
Automation concept

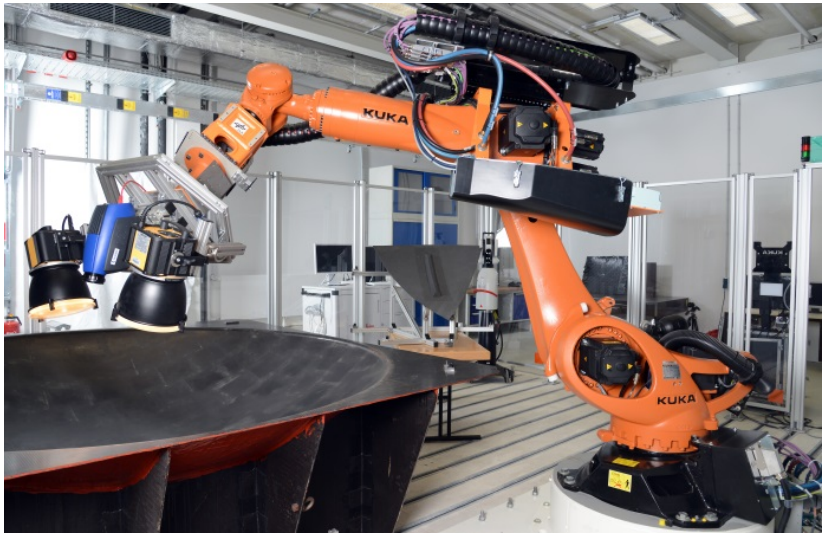
- Description of various usage scenarios
- Concept and evaluation phase and selection
- Integration of thermography system in robot control
- Application of industrial bus technology



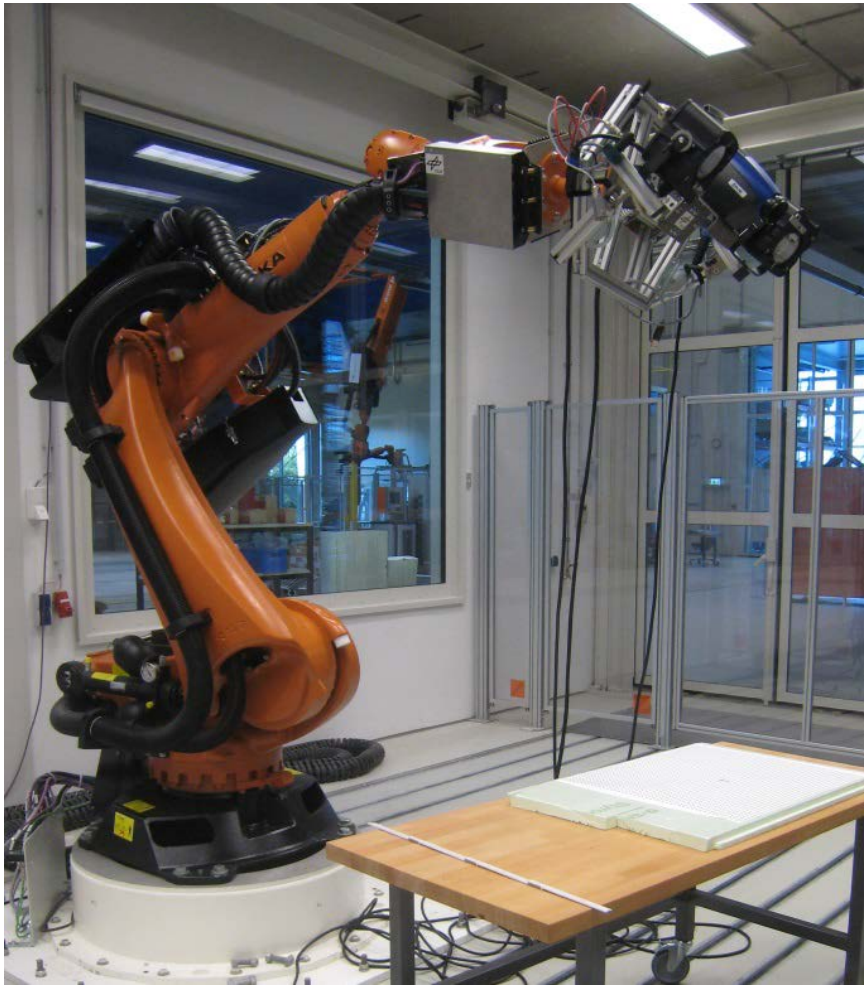
End-effector prototype

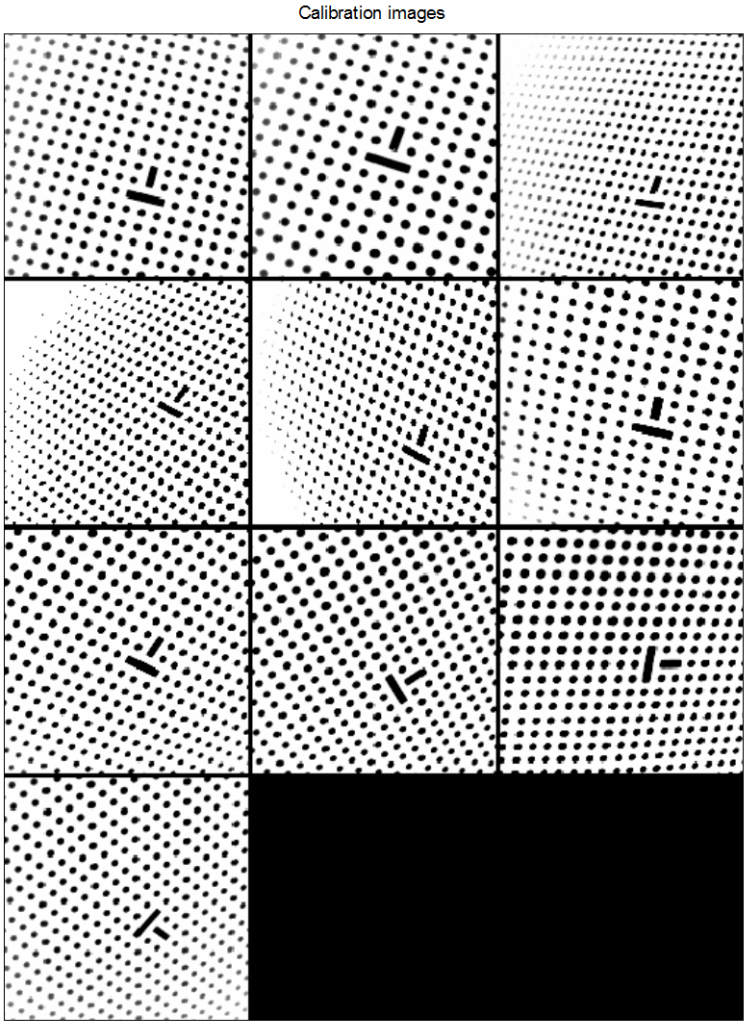
- Flexible set-up
- Ability to carry up to three halogen lamps
- Camera and lamps are adjustable



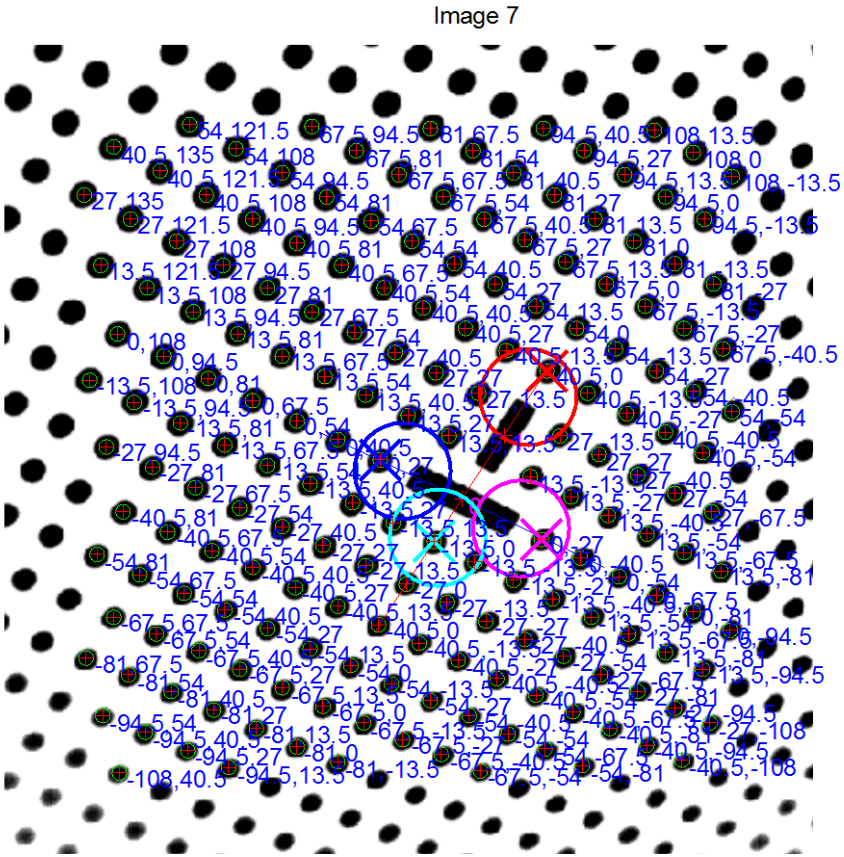


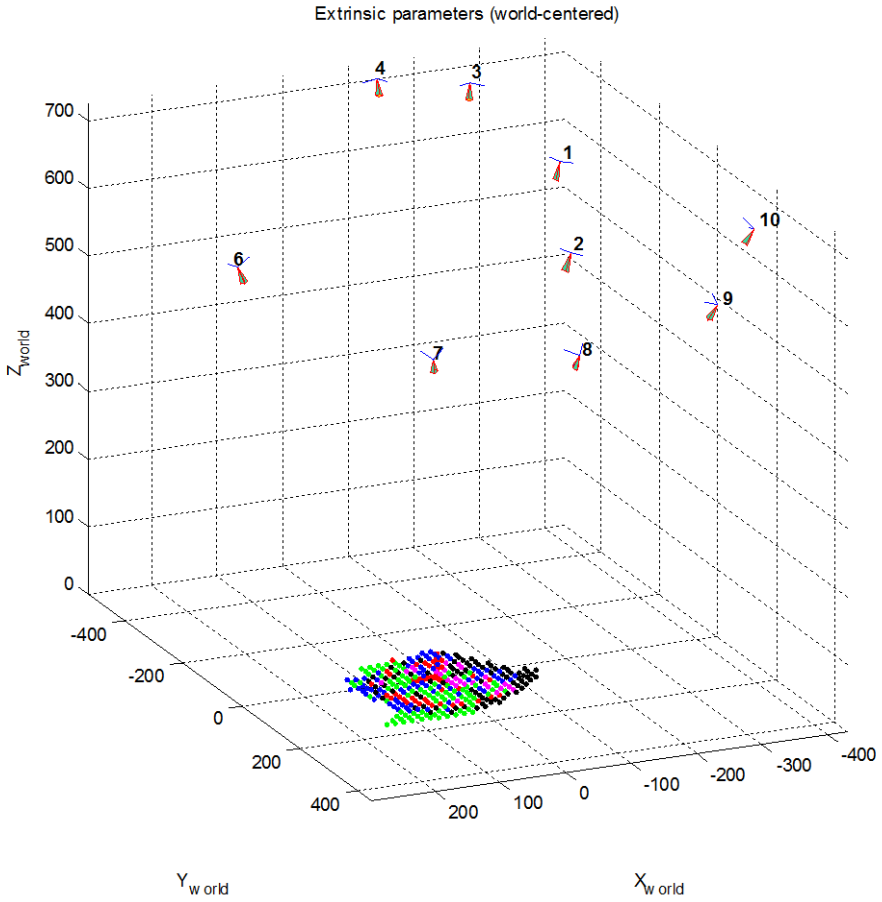
Hand Eye Calibration





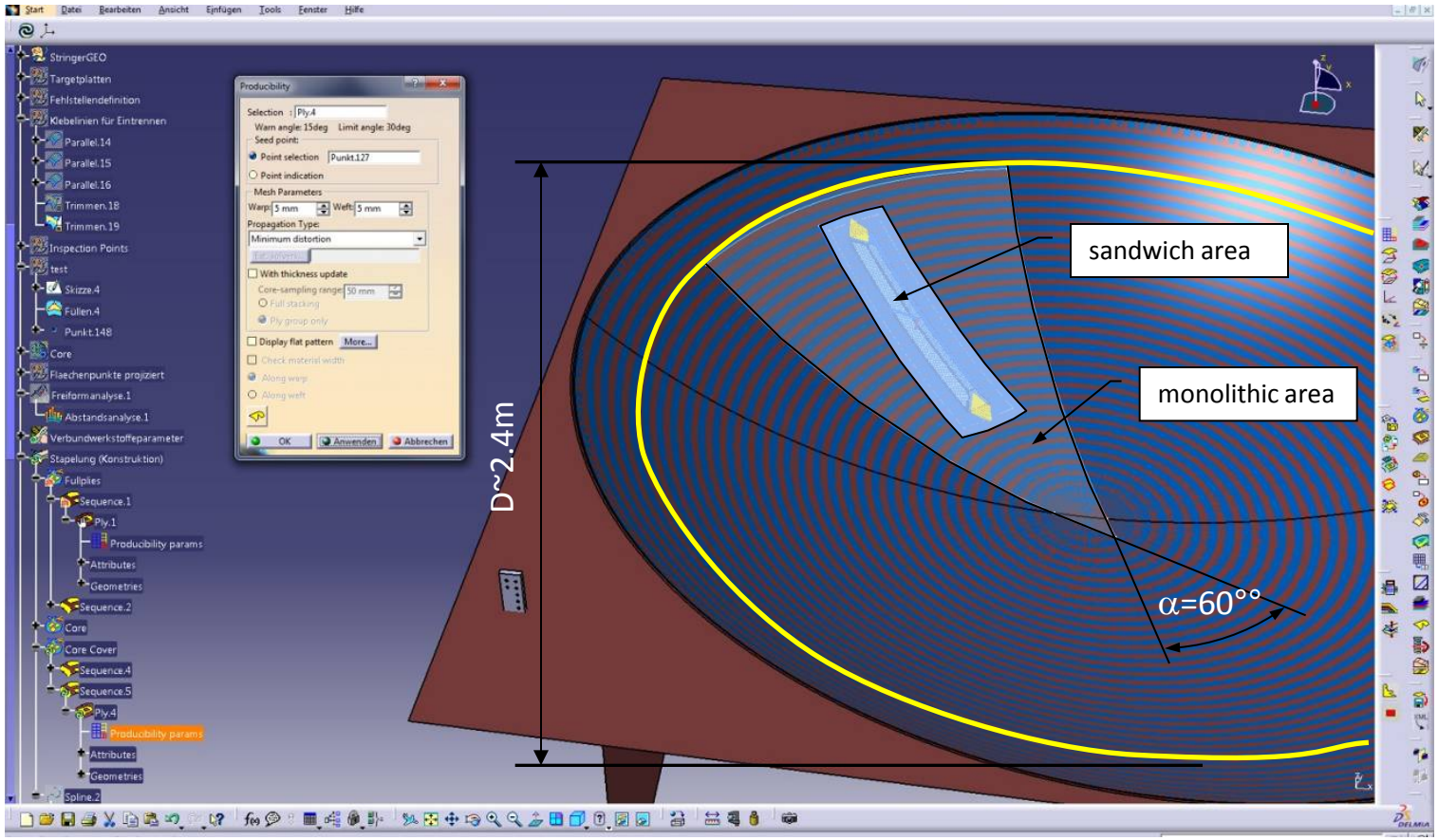
Hand Eye Calibration





- Camera image calibrated to correct optical effects
- Offset values successfully determined (T{X, Y, Z}; R{A, B, C})

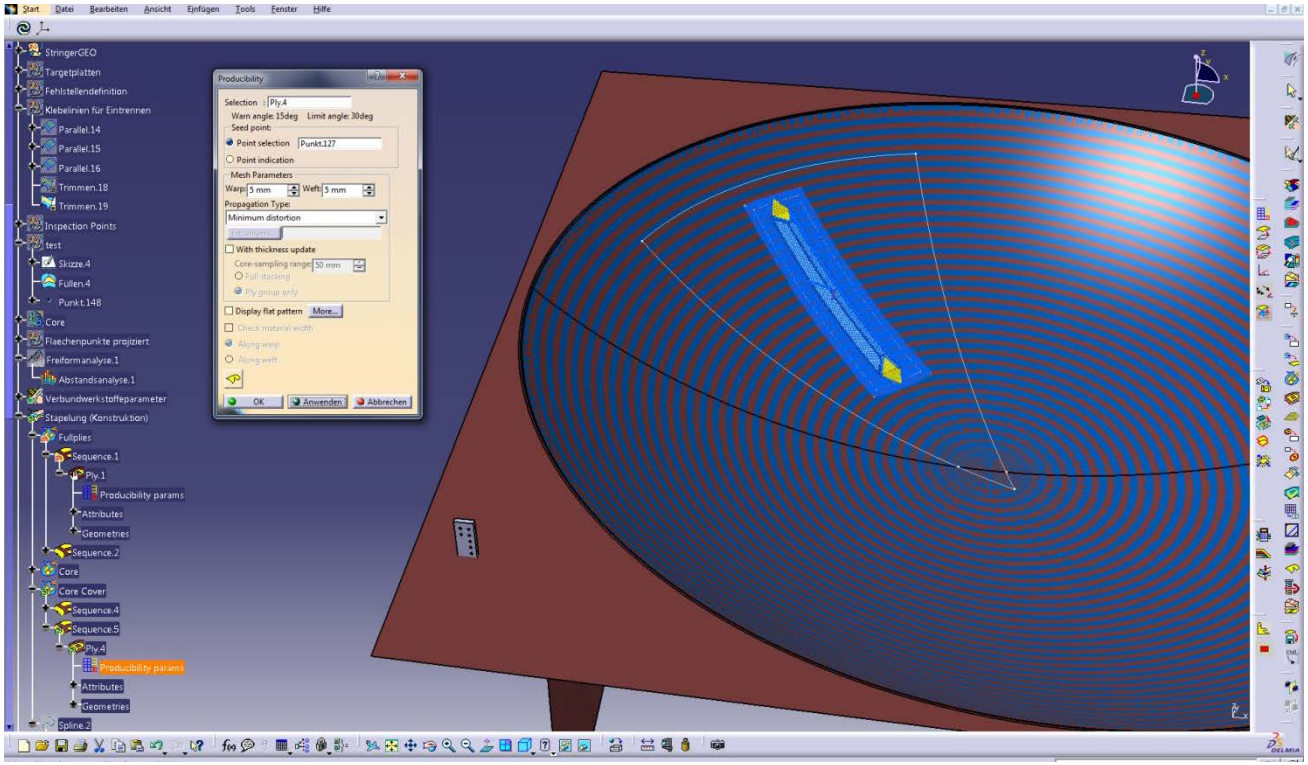
Use case description – Rear Pressure Bulkhead

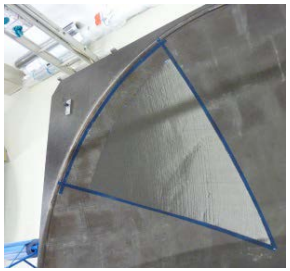


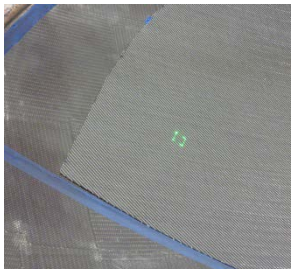
Composite definition

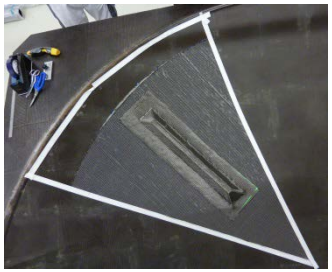
- Non Crimp Fabric - 563g/m² (6/12k rovings)
- Fabric – 200g/m² 2x2 Twill weave
- Resin – 2K Epoxy Larit 135® (RT infiltration and cure)
- Foam core – Polyurethane (PU)
- Layup - symmetric, staggered core cover
- Infiltration process – Vacuum Assisted Process (VAP®)

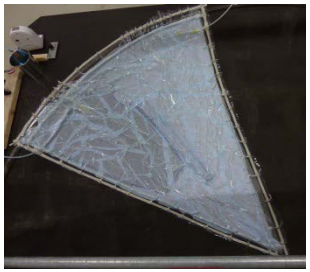
Design and manufacturing of demonstrator



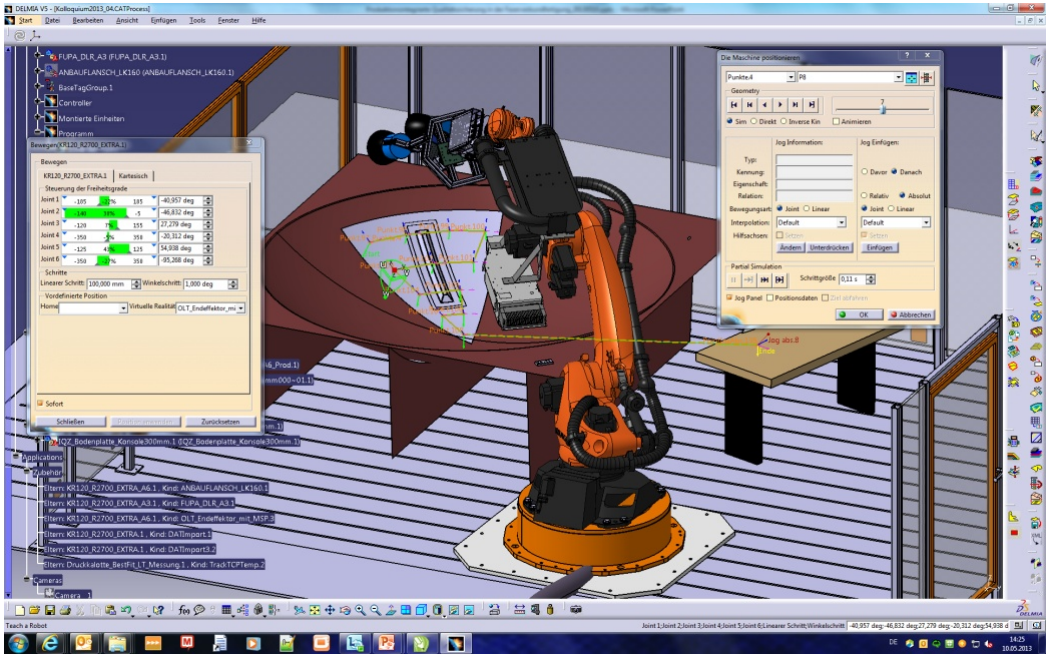




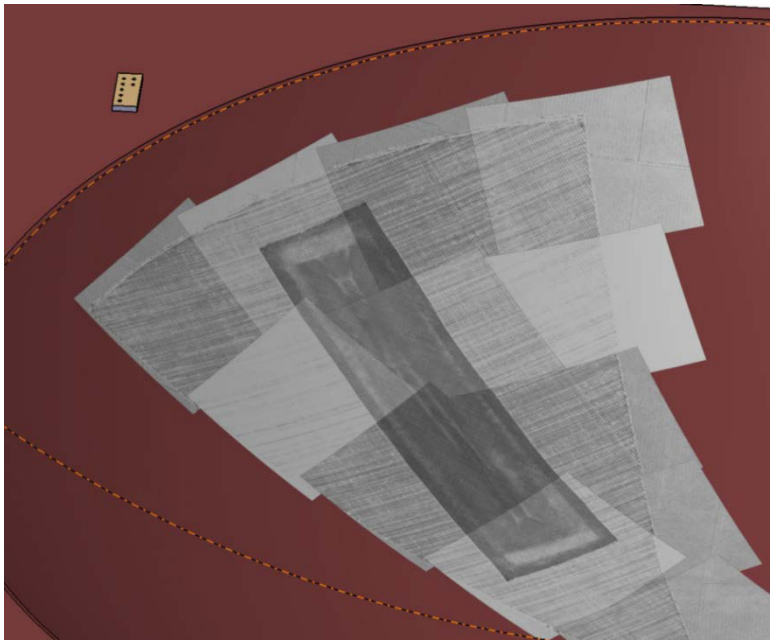




Measurement at preform stage



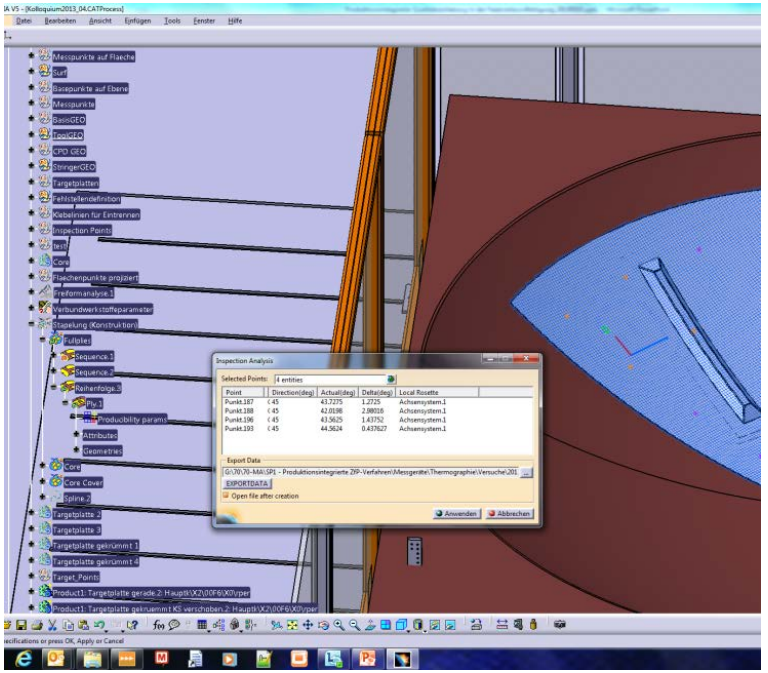
- Offline programming including calibration
- Automated measurement for image registration
- Tiling of each view and transformation into part coordinate system

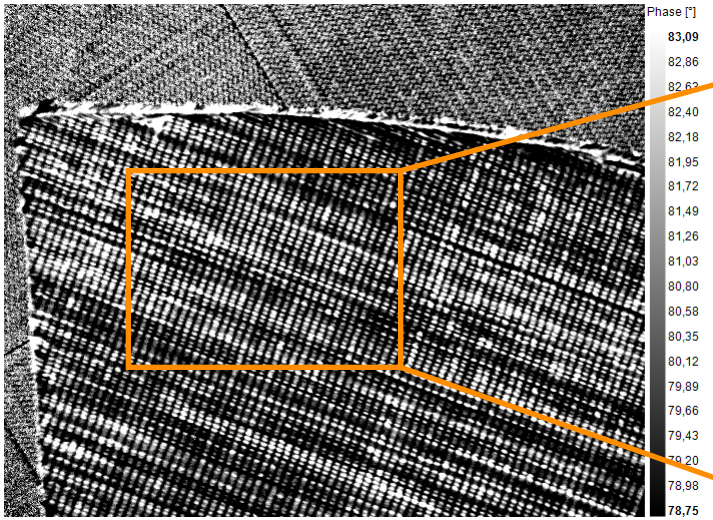


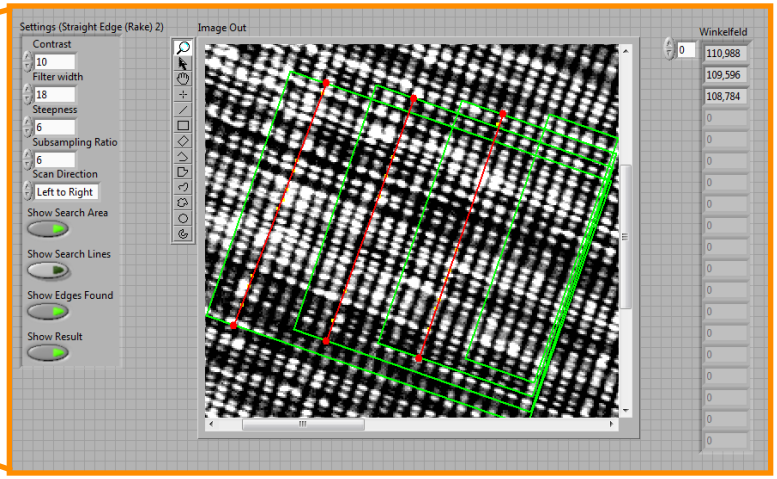
excitation frequency f=0.5Hz

Evaluation on fiber orientation

- Based on phase images
- Measurement of fiber orientation in camera coordinate
- Current work: Transformation into robot coordinates and/or part coordinate system to allow set-actual comparison

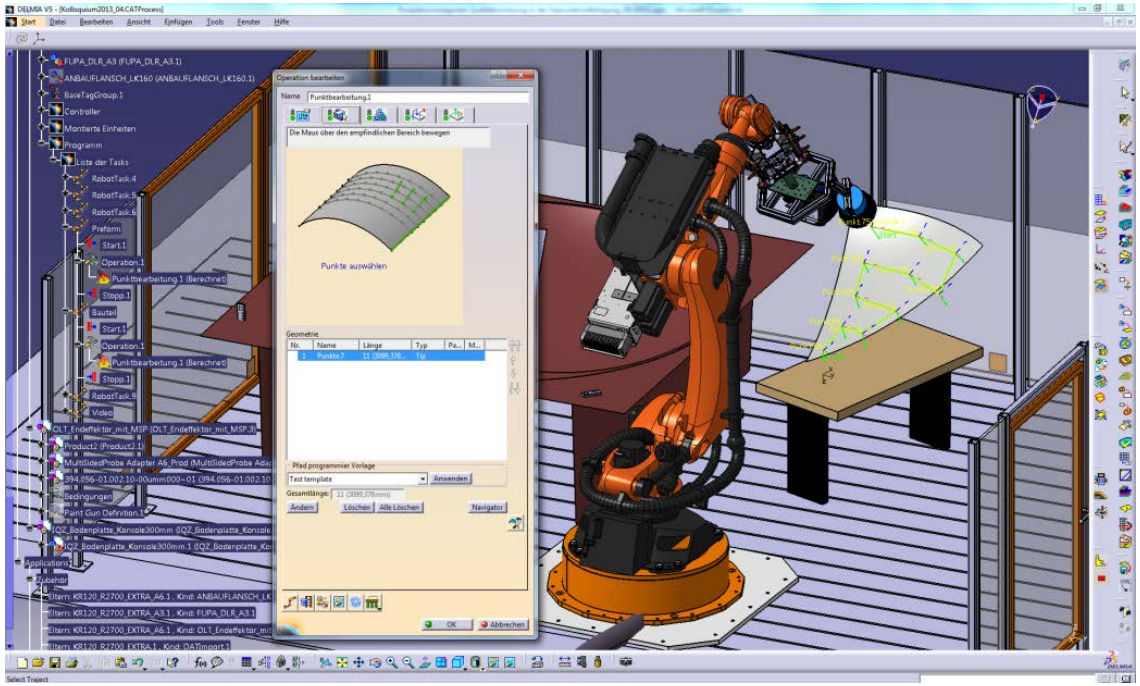




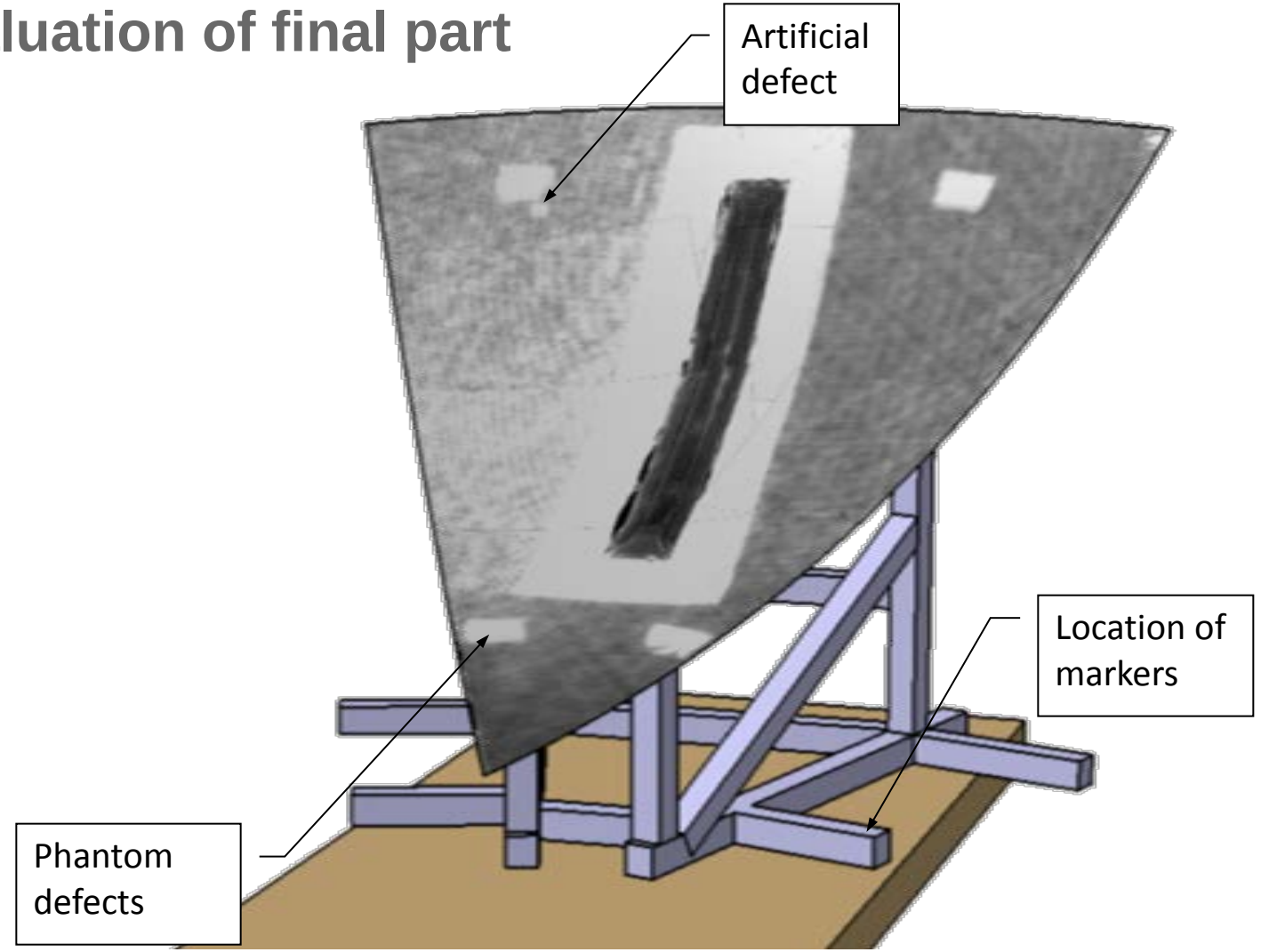


Measurement on final part

- Procedure analog to measurement of preform
- Using different set of Thermography parameters
- 11 fields of view for approx. 1m²
- Duration approx. 12 minutes



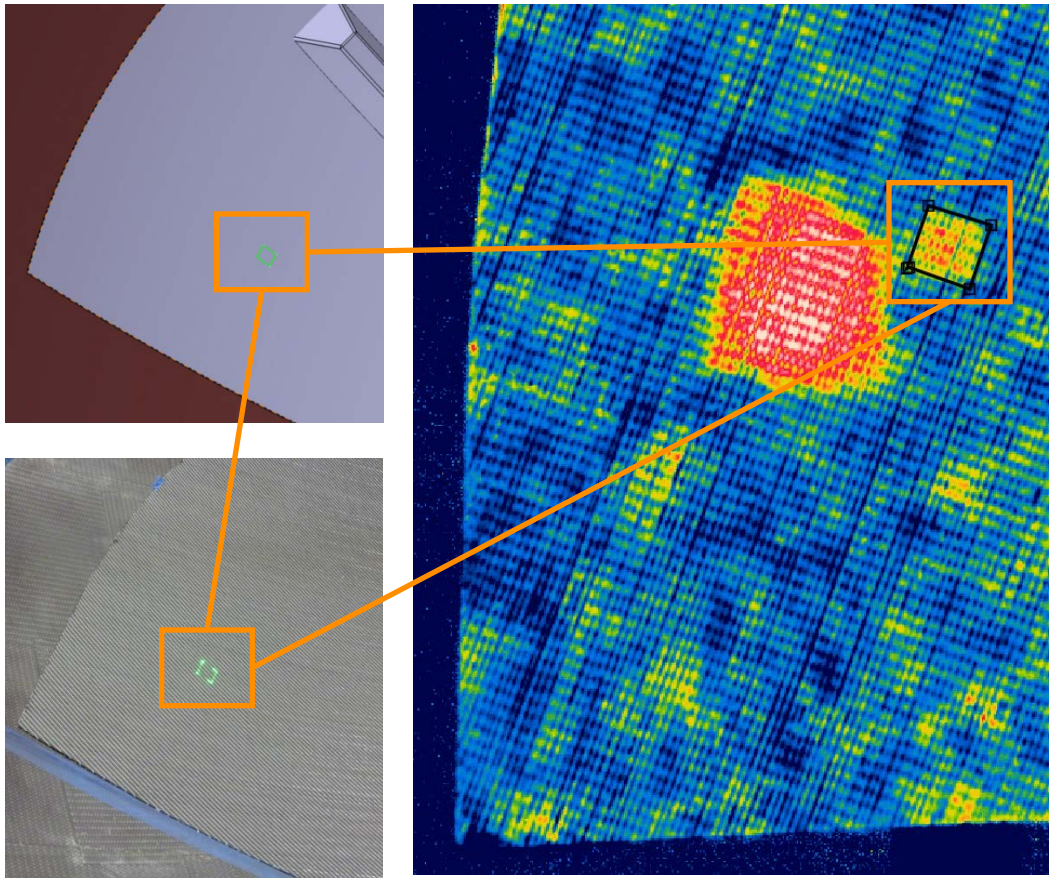
Evaluation of final part



modulation frequency f=0.08Hz

Evaluation of delaminatons on final part

- Based on phase images
- Location, shape and size of artificial delaminations show excellent match
- Inhomogeneities are typical for laminate produced in VAP® technology due to peel ply surface and porosities
- Abundant anomalies arise from part fixtures



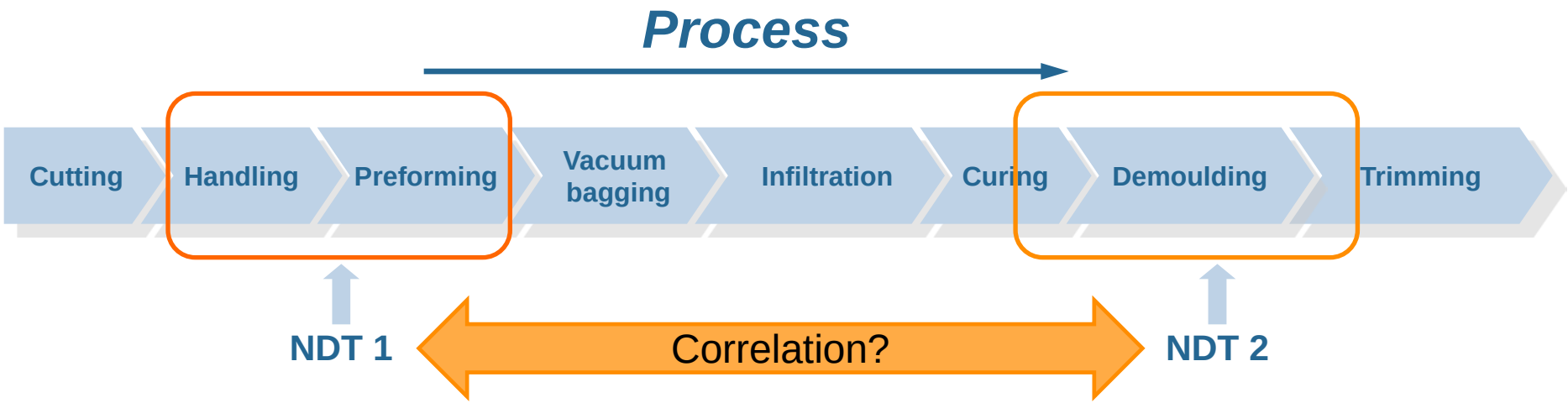
Modulation frequency f=0.08Hz

Summary

- Optically excited lock-in thermography proves to cover observation along the CFRP manufacturing process chain at various steps
- Standardized set-up allows transfer to any other robotic work cell, hence NDT of large parts with complex layup and geometry at full scale
- Data exchange with robots and coordinate transformation for automation and localization of defect
- Use case successfully demonstrated the chosen approach of automated thermography

Outlook

- Investigations on correlation between single steps
- Close loop for engineering purposes
- Accuracy of local part coordinate system on part transfer from one to the next process step needs to be improved



Thank you!
Questions?

Acknowledgements

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AUGSBURG INNOVATIONS PARK

Federal Ministry of Economics and Technology

- Many thanks to the team at DLR-ZLP